Table 5: Seasonality and Likelihood of Occurrence of Pinnipeds (Seals and Sea Lions) near Project Site

Genus and species	Status	Seasonality/ Likelihood of Occurrence
California sea lion *(Zalophus californianus c.)*	Protected under MMPA.	Year-round. Likely.
Northern fur seal *(Callorhinus ursinus)*	Protected under MMPA.	May to November. Extremely remote.
Guadalupe fur seal *(Arctocephalus townsendi)*	Protected, strategic and depleted under MMPA . Threatened under ESA.	Summer and fall. Extremely remote.
Steller sea lion *(Eumetopias jubatus)*	Protected, strategic and depleted under MMPA. Threatened under ESA.	Summer and fall. Extremely remote.
Pacific harbor seal *(Phoca vitulina richardsi)*	Protected under MMPA.	Year-round. Likely.
Northern elephant seal *(Mirounga angustirostris)*	Protected under MMPA.	December to August. Unlikely.
Ribbon seal *(Histriophoca fasciata)*	Protected under MMPA.	Two California sightings. Extremely remote.

Table 6: Seasonality and Likelihood of Occurrence of Sea Otters at Project Site

Genus and species	Status	Seasonality/ Likelihood of Occurrence
Southern sea otter *(Enhydra lutris nereis)*	Protected, strategic and depleted under MMPA. Threatened under ESA.	Year-round. Very unlikely.

Table 7: Seasonality and Likelihood of Occurrence of Sea Turtles at Project Site

Genus and species	Status	Seasonality/ Likelihood of Occurrence
Loggerhead sea turtle *(Caretta caretta)*	Endangered under ESA.	July through September. Remote.
Green sea turtle *(Chelonia mydas)*	Endangered under ESA.	July through October. Remote.
Olive ridley sea turtle *(Lepodochelys olivacea)*	Threatened under ESA.	July through October. Remote.
Leatherback sea turtle *(Dermochelys coriacea)*	Endangered under ESA	July through September. Remote.

Sources for tables: Carretta *et al.* 2001 and 2002; Angliss *et al.* 2001; Howorth, unpublished field notes; USGS 2003; NMFS and USFWS 1998a-d.

6.0 APPENDIX 2: EFFECTS OF UNDERWATER SOUNDS

6.1 Dynamics of Sound Pressure Waves

When a charge is detonated, a chemical reaction causes a large volume of gas to be suddenly released. Such an extremely rapid expansion of gases is capable of severing steel and shattering concrete and rock.

This swift expansion of gases also rapidly displaces water, in the process generating a high-pressure sound wave that travels very swiftly through the water. This wave travels at about 1500 meters a second, about five times faster than sound travels through air. If the detonation is coupled to the sea floor, it can travel through rock at about 5000 meters a second.

Once the gases have been released into the water, the bubbles collapse, resulting in a corresponding fast drop of pressure. With a charge set in deep water, the bubbles can collapse, then reform as they expand on their way to the surface, sometimes causing repercussions. In the shallow water at the project site, however, the bubbles will burst to the surface almost instantly and will not reform because they will be released into the atmosphere as gas, which will rapidly dissipate.

6.2 Shallow Water Effects

When a detonation goes off in deep ocean water, the sound pressure waves theoretically spread equally in all directions, not changing in their uniformity unless they strike layers of different temperature and salinity, or until they finally reach the sea surface or the sea floor. This is called spherical spreading. Considering this uniformity of distribution, estimating sound pressure waves in open water is relatively simple.

By contrast, shallow water detonation models are extremely complex. In shallow water, numerous factors disrupt the uniform spherical spread of waves expected in open water (Richardson *et al.* 1995; Winsor and Howorth 2000).

When a sound pressure wave in shallow water begins to spread, part of it quickly travels through the surface boundary between water and air. Another part reflects off this boundary, usually converging out of phase with the main wave, thus attenuating it. Another part of the wave strikes the sea floor. Again, part of the energy is absorbed, while part is reflected. The reflected component can also converge out of phase with the main wave, further attenuating it. This process becomes even more complicated when the detonation is coupled to the sea floor, which will be the case for this project because the H-piles were driven into the substrate.

The shape of the reflective interface can have a large bearing on how much energy is reflected. When the sea is flat calm, maximum energy is reflected. When it is rough, with choppy swells and breaking whitecaps, considerably more energy is absorbed or reflected in numerous directions rather than concentrated. For the same reasons, rolling coarse sand bottoms absorb considerably more energy than flat hard bottoms (Howorth 1998c and d; 2000). In the immediate project area, the sea floor consists of flat sand, so both absorption and reflection can be expected.

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Occasionally, reflected waves converge in phase with the main wave. When this occurs, higher sound pressure levels can occur farther away from a detonation site. This occurred in some instances during the Mobil Seacliff Pier Decommissioning Project (Howorth 1998c through e). Eventually, however, reflected waves greatly attenuate the spread of sound pressure in shallow water. Thus, in shallow water, sound levels may substantially increase or decrease with distance, which is one reason why estimates made of open water detonations have little relevance for shallow water applications (Howorth 2000; Winsor and Howorth 2000).

Refraction occurs when a sound pressure wave bends as it enters a medium of different density. This can occur when a wave strikes a thermocline, a water layer of different temperature and salinity (Richardson *et al.* 1995). A cold thermocline may be present near the bottom at the project site.

Diffraction occurs when a wave wraps around an undersea feature, such as a rocky reef. Since the sea floor in the immediate area is uniformly flat (Fugro 1999), little diffraction is expected.

Interfaces occur where two different media converge, such as where the sea floor meets the water. Some energy stays in the sea floor, but some is transmitted into the water (Howorth 2000; Winsor and Howorth 2000).

Ducting occurs when trenches or other bathymetric features channel sound (Howorth 2000). Since the sea floor in the immediate area is flat, ducting is not anticipated. The bathymetric contours at the project site are remarkably uniform, consisting generally of a gently sloping sand bottom (Fugro 1999). Sound pressure waves traveling seaward will probably retain more energy, since the angle for reflection continues to fall off as the sea floor deepens. Conversely, rapidly shallowing contours toward shore will enhance reflections, probably resulting in rapid attenuation. When detonations are made during low tides, the attenuation is even greater because the water is even shallower and reflections are even greater (Howorth 1998c through e).

All of these factors, plus the densities of the various media through which sound pressure waves will travel, must be taken into account when designing a shallow water model. For this project, estimates have already been provided so modeling will not be performed. The size, shape, composition, and timing of the charges must also be considered. In the case of pile driving, the size, shape and material of the piles, as well as the specifications of the pile driver itself, must be taken into account.

6.3 Sound Pressure Measurements and Safe Sound Levels

Sound intensity is expressed in decibels (dB), which provide a measure of the magnitude of sound. Decibels do *not* form a linear progression, meaning that 200 decibels would be twice as loud as 100. Instead, they are based on a logarithmic scale something like the Richter scale for earthquakes. A doubling in sound intensity is indicated by a 3 dB increase, regardless of the level of the original sound. For example, a dB level of 63 is twice as loud as 60 dB and a dB level of 180 is twice as loud as 177 dB. For every 10 dB increase, the intensity increases ten times. Thus, 210 dB is ten times as loud as 200 dB and 220 db is a hundred times as loud as 200 dB.

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For decibels to have relevance, they must be referenced to pressure. A micropascal (μPa) is a measurement of pressure equal to one-millionth of a pascal. (One pascal represents a one-newton force exerted over one square meter.) The reference pressure used for underwater sounds is 1μPa. Thus, underwater sound pressure level (SPL) measurements are expressed as X dB re 1μPa, which provides a measure of the magnitude of sound in decibels referenced to pressure in micropascals. In air, the reference pressure is 20μPa, rendering decibel comparisons of familiar airborne sounds, such as rock bands and jet engines, of no relevance to underwater sounds.

Sound pressure can also be expressed as the source level (SL). This is the average theoretical peak pressure within one meter of the sound source, expressed as X dB re 1μPa - m. Such a measurement is used to compare modeled or measured sound pressure levels at various ranges and distances from the sound source with the source level itself.

Peak sound pressure can also be expressed in pounds per square inch (psi). This represents the peak overpressure itself without adding the ambient pressure at a given water depth. Absolute pressure equals the ambient pressure at a given depth *plus* the overpressure. In sea water, pressure increases at about 0.44 psi per foot of depth. At sea level, the atmospheric pressure is 14.7 psi, whereas at 33 feet, this pressure is doubled to 29.4 psi, which is sometimes called two atmospheres. As an example of absolute pressure, when an ambient pressure of 29.4 psi is added to a peak overpressure of say, 20 psi, the absolute pressure becomes 49.4 psi.

These two ways of measuring peak sound pressure (decibels referenced to pressure and psi) provide a momentary measure of the peak sound pressures from a detonation. For many years, peak underwater sound pressure levels of 180 dB re 1μPa or above were thought to have the potential of causing harm to marine mammals. This measurement was applied to numerous past project with the acceptance of NOAA Fisheries (Howorth 1996a and b; 1997a through c; 1998a through e). A safe level for fish was considered to be about 200 dB re lμPa. However, peak sound pressure is most significant at or near the source because it is highest there and takes place over the shortest period of time. At longer ranges, however, peak pressure measurements are somewhat less useful because they do not express the amount of time the overpressure is applied to an animal. The farther away from a detonation site, the longer the sound pressure wave becomes, much like the widening ripples from a pebble tossed into a pond.

Measurements of sound energy provide a measure of sound pressure times the duration of the sound pressure wave. Knowing the sound energy provides a measure of how long pressure is applied to an animal. This is useful because the longer substantial pressure is applied to an animal, the greater the potential for damage. Thus, knowing the sound energy can be useful in assessing potential impacts at greater ranges. Sound energy is particularly useful when large detonations occur, such as the U.S. Navy's ship shock trials, which involved 10,000-pound charges (Howorth 1992; 1994a, b and c).

Sound energy is often expressed as X dB re 1μPa^2 - s (decibels referenced to one micropascal squared per second). A threshold level of 182 dB re 1μPa^2 - s is currently accepted by NOAA Fisheries as being the threshold at which minimal, recoverable auditory trauma (TTS) may occur to marine mammals (Fahy, pers. comm.). The risks of injury increase with increased pressure. Alternatively, NOAA Fisheries also accepts 12

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psi peak pressure as a threshold level. Whichever level is attained first becomes the threshold limit. Although these thresholds have been accepted in past projects, they do not represent any standard that has been adopted by NOAA Fisheries. The approach taken by the regulatory agencies has been to use the current state of knowledge in a prudent, conservative manner and to rely upon past successes as indicators. New means of calculating threshold levels may be released by NOAA Fisheries in the near future (Fahy, pers. comm.).

Such measurements are applied to the establishment of hazard zones by estimating or modeling sound pressure levels to determine at what range from a detonation site such values would be reached. A safety margin is provided to allow for errors in estimates or models. In projects involving multiple detonations over a period of time, measurements can be made of received sound levels at various depths, distances and directions from a detonation site. These measurements can then be used to assess the accuracy of the estimates or modeling.

In projects involving repeated impulse sounds, such as those generated by pile driving activities or geophysical airguns, still other means of setting thresholds have been applied. Different means are employed for such projects because the noise is repeated over time rather than divided into distinctly separate events. With such projects, average peak pressure, expressed as X dB re 1μPa – rms (root mean square) has been used.

During a recent geophysical project, 160 dB re 1μPa – rms was used as a threshold for Level B harassment of baleen whales and the sperm whale, which are thought to be more sensitive to low frequency sounds, and 180 dB re 1μPa – rms was applied to pinnipeds and small odontocetes. This resulted in two hazard zones: one at 82 meters (270 feet) for pinnipeds and small odontocetes; the other at 1000 meters (3281 feet) for baleen whales and the sperm whale (Howorth 1998f). The range of the hazard zones was determined by estimating the ranges at which the threshold levels would be reached based on the source level of the airguns. More recently, during the pile driving project at Lease 421, 160 dB re 1μPa – rms was used to establish a 500-foot hazard zone (Greene 2001a and b).

6.4 Sound Frequency Spectrums of Underwater Detonations and Pile Driving

Knowing the frequency (pitch) of sounds produced by a detonation or by pile driving operations is useful when the range of frequencies in which an animal hears is known. The assumption is that if an animal can't hear a sound it will not be harassed by it. However, animals as well as humans can detect sounds beyond their normal range of hearing if such sounds are loud enough. Also, they can be injured by sounds they cannot normally hear if such sounds are sufficiently loud.

As mentioned in Section 3.4.2, sound frequencies are measured in hertz (Hz) and kilohertz (kHz). One hertz equals one cycle per second, which is an extremely low frequency. One kilohertz equals 1000 hertz.

The sound spectrum at a detonation site is extremely broad. However, high frequency sounds quickly attenuate from absorption and scattering as range increases. Thus, harassment from high frequency sounds is not an issue at longer ranges.

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